§28. Dynamic Simulation of a Helium Liquefier

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Dynamic simulation of a helium liquefier has been conducted; using a Cryogenic-Process Real-time SimulaTor (CPREST), which has been jointly developed by NIFS and NSC (Nippon Sanso Co.) as a part of the National Laboratory and Industry Collaboration program. The C-PREST is primarily used to analyze a helium-refrigeration-plant operation. It is also designed to utilize as a platform for the plant process-analysis tool, to study coupled cryogenic phenomenon and to train operators.

To demonstrate the capability of C-PREST, a dynamic simulation of a helium liquefier has been conducted. FIG 1 shows a Process and Instrumentation diagram (P&ID) for a helium liquefier, which consists of two expansion turbines, seven heat exchangers, an LN_2 precooler and a LHe reservoir. The simulation model was implemented on the PC and its process control was programmed with an EWS. The simulation was performed with an automatic sequence program of a real refrigerator to compare the simulation result with an actual operation.

Fig. 2 shows the comparison of cooldown curves. The initial condition was set to have some liquid within a liquid helium dewar. At the startup of operation, the temperature of the liquefier cold box is lower than that of the simulation since the liquefier was not completely warmed-up. As the cooldown process continues, this discrepancy gets smaller except for the ET2 outlet temperature, TI 11. For the case of liquefier, TI 26 increased at 2.8 hours of operation because of the warm gas in the transfer line, corresponding to the opening of the JT valve. This affects the time to start the liquefaction as well as the closure of the JT-bypass valve. Even though the time to start the liquefaction was not the same, liquefaction rates (100 liter/hr) are comparable for both cases.

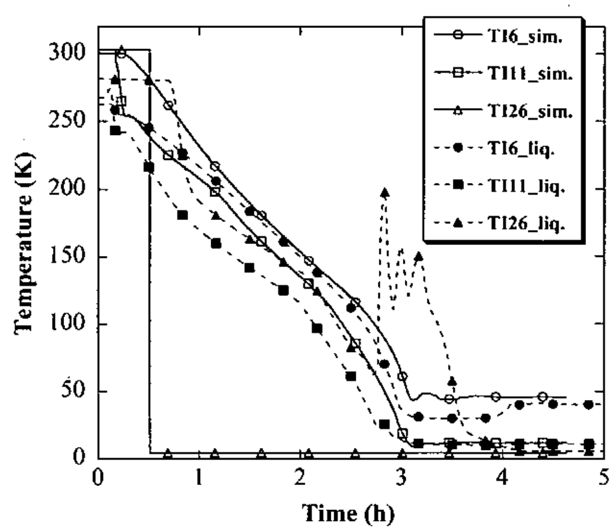

Fig. 2. Cooldown curve compared with a liquefier.

The discrepancy at TI 26 is due to the simplification of the modeling. The priority for C-PREST is to achieve the real-time dynamic simulation so that the CPU time must not be impacted by too much modeling detail. In this case, the GHe temperature increase in the transfer line and the dewar are neglected. As a result, the model fails to predict operation disturbances as shown in the Fig. 2.

We demonstrated a liquefaction process of a helium liquefier with C-PREST. This is the first time to perform the liquefaction with a dynamic simulation. Even though some simplification of modeling each component such as, a heat exchanger, a dewar, the results are accurate enough to study plant process and train operators. The results encourage us to proceed to model a LHD helium refrigerator/liquefier for the next project, which consists of 7 expansion turbines and 14 heat exchangers.

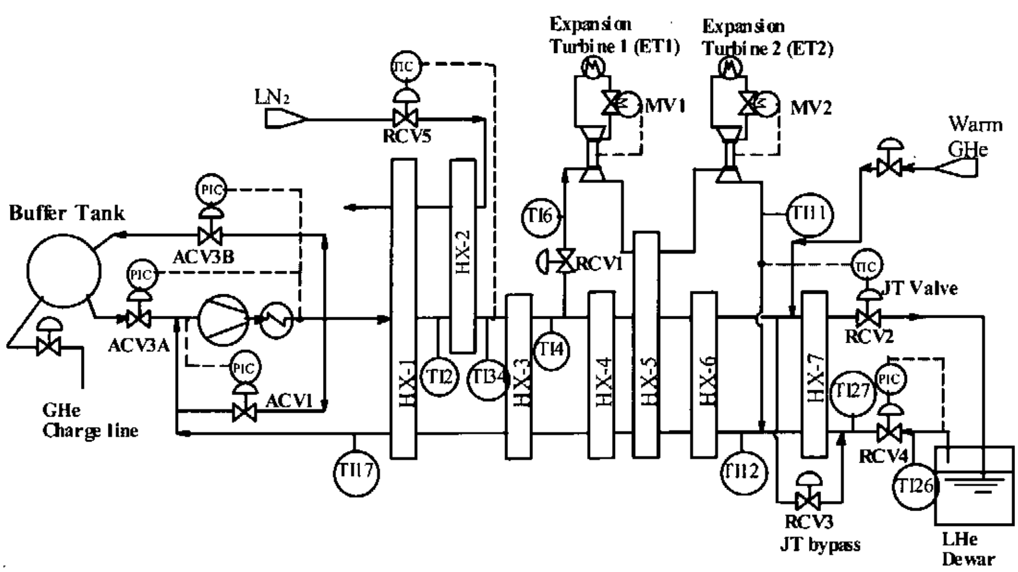

Fig. 1. Process and Instrumentation Diagram of a helium liquefier.